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14APR03 E799788-1 D03081
P01/7700 0.00-0308446.4

Request for grant of a patent

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14 APR 2003

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1. Your reference

04PAT/4861BCH03PV47

2. Patent application number
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0308446.4

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Sentec Ltd
Brunswick House
65-69 Newmarket Road
Cambridge. CB5 8EG.

Patents ADP number *(if you know it)*

8299893002

If the applicant is a corporate body, give the country/state of its incorporation

U.K.

4. Title of the invention

Low-power Magnetic Flow Meter

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

~~Sentec Ltd. (as above)~~ MAGUIRE BOSS
5 Crown Street
St. Ives
Cambridgeshire

Patents ADP number *(if you know it)*

~~8299893002~~
7188725001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
—		

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes.

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Patents Form 1/77

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Continuation sheets of this form	
Description	6
Claim(s)	1
Abstract	1
Drawing(s)	2

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10. If you are also filing any of the following, state how many against each item.

Priority documents	–
Translations of priority documents	–
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	1
Request for preliminary examination and search *(Patents Form 9/77)*	–
Request for substantive examination *(Patents Form 10/77)*	–
Any other documents *(please specify)*	–

11. I/We request the grant of a patent on the basis of this application.

Signature B Bumpstead Date 14/4/03

12. Name and daytime telephone number of person to contact in the United Kingdom 01223 - 303800

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Low-power Magnetic Flow Meter

Field of the Invention

This invention relates to the field of conductive fluid flow metering, particularly but not exclusively for use as a utility water meter.

Background

Solid state water meters are an attractive technology for utility metering, particularly when coupled with one of the many available methods for remote meter reading. In a conventional utility water meter, a mechanical flow transducer (typically positive displacement or single/multi-jet turbine) is coupled to a register mechanism that measures the number of repetitive cycles of the transducer. This mechanism is often a mechanical odometer. To interface this to the electronics required for remote meter reading can be cumbersome and expensive. One solution is to use a solid-state register, with digital counters and LCD and display.

This invention integrates the flow transducer with the register, by using a solid-state flow transducer. There are a number of candidate technologies for this application. These include:

- Ultrasonic time-of-flight
- Fluidic oscillator
- Magnetic flow meter

The key requirements for the transducer are;

- Basic accuracy/linearity
- Dynamic range
- Power consumption
- Cost

Historically, magnetic flow meters have been ruled out of this application, on the basis of their relatively high power consumption. In other respects, magnetic flow meters are easily able to meet the specifications of a utility meter, and are often used for metering larger-sized distribution pipes.

This invention described implementations of magnetic flow meters with significantly lower power consumption than existing meters, allowing their use in battery-powered utility metering applications.

Summary of the Invention

This invention describes a magnetic flow meter operated using periodically switched remenant magnetic field, in which the signal processing used to analyse the signals from the flow transducer is energised intermittently with a low duty cycle, and a passive circuit is used to filter the signal from the electrodes, in particular whilst the main signal processing electronics is not energised. Using a remenant field magnetic circuit means that power is only required to change the state of the magnetic field, whilst the use of a passive filter means that a lower bandwidth can be achieved without having to have an active filter circuit energised continuously. It also allows the use of lower-cost, higher-performance components that use more current, because these are only energised with a low duty cycle.

The combination of these two features allows operation at significantly lower power levels than other magnetic flow meters of comparable performance. The choice of electrode materials to achieve a low-enough spectral noise density from the electrodes allows operation at lower field levels and lower switching frequencies, and hence further reduces the power consumption of the flow meter.

Brief Description of the Drawings

Embodiments of the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates a flow tube,
Figure 2 illustrates a flow measurement system
Figure 3 illustrates the cross-section of a radial, remenant flow meter
Figure 4 illustrates an axial cross-section of the design in Figure 3.

Detailed Description

Figure 1 shows a cross-section diagram of a one embodiment of remenance magnetic flow tube. The flow tube, 101, contains a pair of electrodes, 102, disposed across a diameter of

the pipe, with at least part of one surface of each electrode in intimate contact with the fluid in the pipe. A pair of magnetic pole pieces, 103, is disposed across the orthogonal diameter of the pipe. A magnetic circuit, 104, links the two poles pieces, 103. Said magnetic circuit, 104, contains one or more elements exhibiting magnetic remenance. A set of coils, 105, is wound around part of the magnetic circuit, 104. The residual magnetic field in the magnetic circuit, 104, may be altered by applying a suitable current waveform through the windings, 105.

Figure 2 shows a block diagram of the meter. The electrodes, 102, are connected to signal conditioning means, 201, incorporating passive filter elements which filter the signals from the electrodes without the needs for active amplification. The output(s) from the signal conditioning are passed to the amplification and analogue-to-digital conversion (ADC) means, 202. Digital data from this is passed to the digital processing means, 203. Said digital processing means controls the power and conversion time of the ADC, 203, and also controls a current source, 204, which is able to control the current through set of coils 105 in such a fashion as to alter the remenance of the magnetic circuit, 104. The processor, 203, is also connected to display means, 205, and, optionally, one or more communication means 206.

The principle of operation of the remenant system will now be described. The magnetic circuit, 104, may be magnetised in three different states, such that the magnetic field developed across the flow tube, 101, is one of two substantially equal but opposite polarities ("forward" and "reverse"), or substantially zero.

The system typically operates on a periodic cycle, so an arbitrary starting point is assumed, where the field across the flow tube is "forward". Water flow through the flow tube generates an emf between the electrodes, 102, using the same principle as in a conventional magnetic flow meter, and the purpose of the measurement system is to obtain a measure of this emf (and hence the flow rate), and to integrate this over time to calculate the total volume that has passed through the flow tube.

The signal conditioning means, 201, filters the signal across the electrodes to obtain a low-pass filtered signal at the input to the amplifier and ADC, 202. The filtering circuitry in 202

is passive and remains unpowered for this period, and suitable switching components are used to isolate, where necessary, 201 from 202 and 102. The processor, 203, remains in a low power mode, waiting for an appropriate delay whilst the signal from the signal conditioning is passively filtered. Once this delay has elapsed, under command of the processor, 203, the circuitry in 202 is briefly energised, and the filtered value at the output of the signal conditioning, 201 is amplified, filtered further as appropriate, sampled using the ADC, and communicated to the processor, 203.

Once the sampling process is complete, the circuitry in 202 is powered down, and the current source, 204, is commanded to generate a suitable current waveform to reverse the polarity of the remenant field generated by the magnetic circuit, 104, such that the field across the flow tube, 101, is now "reverse". During this switching period, the circuitry in the signal conditioning, 201, may be disconnected from the electrodes to prevent any switching artefacts from disturbing the signal.

The processing means, 203, then again waits in a low power state, to allow the signal at the output of 201 to stabilise, before again energising 202, sampling the signal at the output of 201, and commanding 204 to flip the field polarity to "forwards" again. This periodic cycle is repeated continuously.

The processor, 203, calculates the signal from the flow tube caused by flow as the difference between the values measured with "forward" and "reverse" field. These values are digitally filtered and scaled to calculate an instantaneous flow rate (fluid volume volume/time), and this signal is integrated over time to calculate total fluid volume.

The display, 205, displays the total integrated fluid volume through the flow tube. If appropriate, the display may also show other parameters relating to either the historical flow of fluid through the flow tube, or other operational or identification parameters typically used in utility metering.

The communication means, 206, allows one or more fundamental or derived quantities from the basic flow measurement to be sent across a communications interface to a reader

or a wider network, to allow remote meter reading. Such communication means are well known in the art.

By way of example, but without limitation, some typical examples of the field levels and switching frequencies that might be involved are described below. In an embodiment design for a 0.5 inch diameter water meter, the field level from the remenant system would typically be ±1000 A/m. The field is reversed ten times a second, and just prior to each reversal, the amplifier and ADC, 202, are energised for 100 μs to measure the passively filtered signal at the output of 201. At the minimum flow rate of 0.25 gpm for this type of meter, the emf generated at the electrodes is of the order of 2 μV. The typical noise at the electrodes at 5 Hz is around 50-100 nV/root Hz (there is a Johnson noise component to this, but generally the electrode itself contributes noise.). In an integration time of 30s (a bandwidth of 0.03Hz), the noise is 9-18 nV, and the measurement error is 0.5 to 1%, within the specifications required for this grade of meter by the AWWA. The power required to switch the magnetisation is strongly dependent on the remenant material, the coil design, and the presence of conductive materials that lead to eddy current losses. The minimum power is the energy stored in the magnetic field in the air gap of the magnetic circuit multiplied by the repetition frequency of the field reversal multiplied by 2. This figure can be calculated by methods well known in the art.

The electrode noise influences the field level required in the flow tube to achieve a particular signal/noise ratio and measurement bandwidth. Electrodes are frequently chosen in magnetic flow meters for their immunity to corrosion effects – for example, stainless steel or Hastelloy. However, alloys typically have poor electrical noise characteristics when used as electrodes. Good results can be obtained using materials such as gold, platinum or graphite. In the presence of chlorinated water, a metallic silver electrode can be engineered to form an Ag/AgCl reference electrode system – this has particularly good noise performance, and can significantly reduce the field levels required to achieve a particular signal/noise ratio.

Further Embodiments

The geometry of the flow tube can include all methods known in the art. Without limitation, these include rectangular (including square) and radial configurations. In one

particularly favourable embodiment, shown in Figure 3, the magnetic circuit comprises a permeable cylinder, 302, an outer permeable hollow cylinder, 307, radial segments, 306, partly filling the volume between the pipe wall and the permeable cylinder, 305, and a remenant element, 303. The remenant element is wound with a set of coils, 105, to allow the field in the magnetic circuit, 104, to be altered by passing a suitable current waveform through them. The interrogating field is set up in the region between 302 and 307, as depicted by the parallel arrows in the illustration.

A cross-sectional view is shown in Figure 4. The electrode system, 401, consists of an insulating substrate, extending beyond the permeable core, 302, by at least a pipe diameter. On each surface of the electrode system, 401, individual electrodes are formed, typically extending no farther axially than the axial length of 302. The electrodes on the top side of the substrate form one pair of electrodes, 102, and the electrodes on the opposite side form a second pair of electrodes. These electrodes would typically be connected either in series or parallel, and connected to the input of the signal conditioning section., 201. A particularly advantageous method to form the electrodes is to use a printed circuit board type of construction for the electrode system, 401. The electrodes can be formed from the surface conductors on the circuit board, which can also advantageously be used to interconnect the electrodes, and to connect to the electronics, 201, 202 etc.

The electrode material affects the system performance. Gold-plated printed circuit board may be used to form the electrode system to give low noise. Alternatively, high-purity graphite may be used – in this case, the graphite may be used as part of the structural element of the flow tube. As described silver reference electrodes may also be used in situations where chlorinated water has led to the generation of chloride ions in solution.

The electronics, 201 to 206, critically affects the system power budget and cost. A number of techniques may be employed advantageously to null out parasitic DC emf's generated by the electrodes, 102, as a result of surface contamination, and hence improve the dynamic range of the converter.

Claims

1. A fluid flow meter based on magnetic induction, characterised in that -
   - a magnetic field is generated across the fluid by one or more elements exhibiting magnetic remenance
   - conductive fluid flow generates an emf between pairs of electrodes as it passes through this field
   - passive signal conditioning elements filter this emf
   - periodically energised components measure this filtered signal
   - processing means calculate the flow rate from the sampled filtered signal

2. A fluid flow meter as described in claim 1 in which the passive conditioning uses at least two of resistors, capacitors and inductors
3. A fluid flow meter as described in any of the preceding claims in which the field polarity is periodically reversed
4. A fluid flow meter as described in any of the preceding claims in which the electrodes are chosen from a set of materials including gold, carbon (in any form), platinum or solver
5. A fluid flow meter as described in any of the preceding claims applied to utility metering
6. A fluid flow meter as described in any of the preceding claims for use in domestic utility metering
7. A fluid flow meter as described in any of the preceding claims incorporating a communication capable of sending data to a remote point.
8. A fluid flow meter as described in any of the preceding claims in which the electrodes are formed as a layer of a printed circuit board.

Abstract

The present invention relates to a system for measuring fluid flow by magnetic induction, using a periodically switched remenant magnetic field, in which the signal processing used to analyse the signals from the flow transducer is energised intermittently with a low duty cycle, and a passive circuit is used to filter the signal from the electrodes, in particular whilst the main signal processing electronics is not energised.

FIGURES

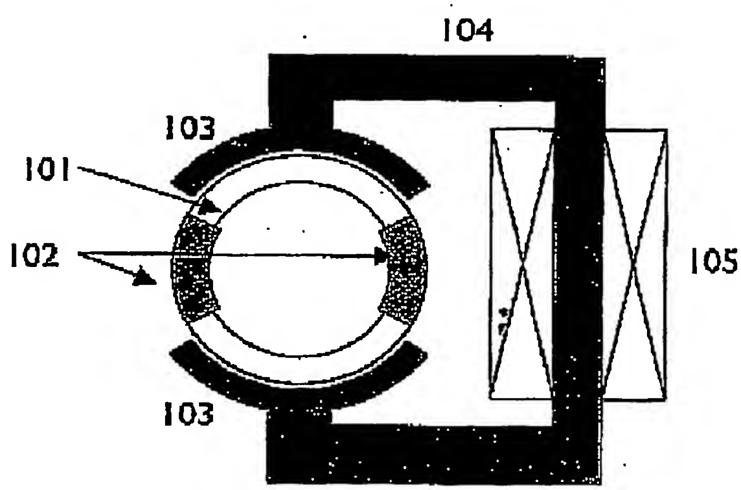

Figure 1

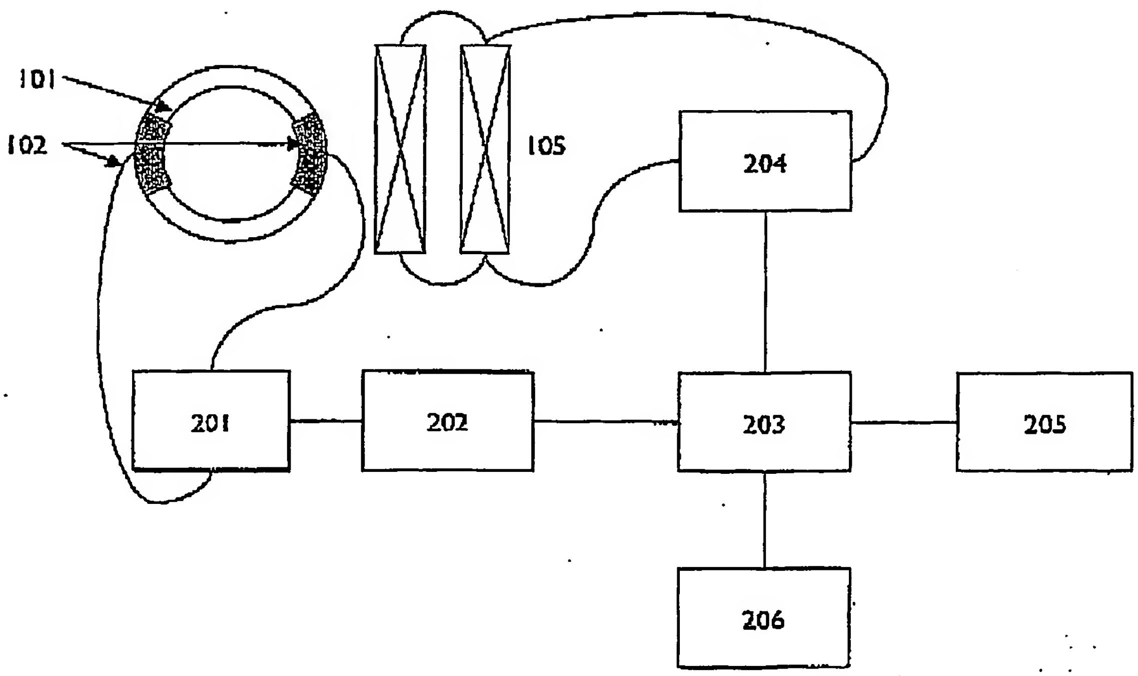

Figure 2

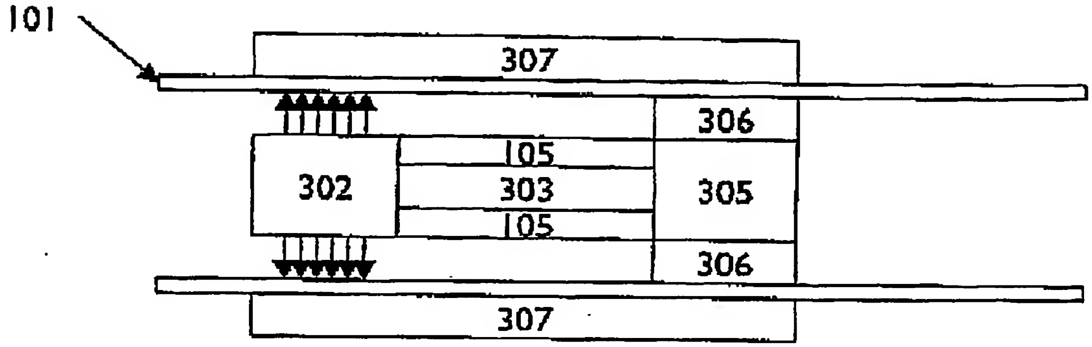

Figure 3

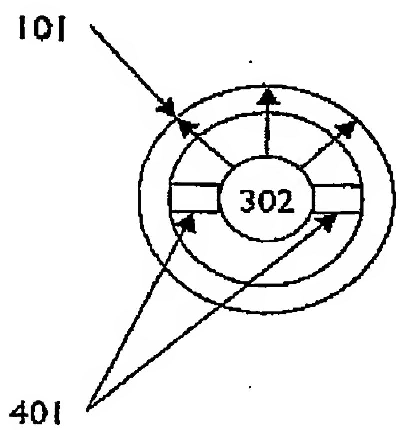

Figure 4

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